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Renewable energy for sustainable development in Africa: a review

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Abstract

Renewable energy usage in Africa has been reviewed using South Africa, Egypt, Nigeria and Mali as case studies. The various national energy policies of these countries were analysed and areas that require attention to achieve sustainability were highlighted. On the overall, the success of sustainable development in Africa lies in addressing the imminent energy crisis in the continent. Excessive usage of fuel wood is already creating considerable environmental problems especially in the Sahel. Africa has all the potentials to solve its energy problems if appropriate infrastructural support can be provided for harnessing the abundant renewable resources in the continent, and if skills are pooled together and experiences shared in addressing the key issues.

Keywords: Renewable energy; Sustainable development; Environment; Africa

Contents

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1. Introduction

Sustainable development has been at the center of recent policies and development plans of many African countries. This is a pattern of development that delivers basic environmental, social and economic services without threatening the viability of natural, built and social systems upon which these services depend. In terms of development indices, energy consumption is a recognized indicator. However, across the globe, as many as two billion people have no access to electricity [1]. A large proportion of these people live in Africa, a continent with greater availability of renewable energy resources. Most African countries lack much of the basic electric power grid infrastructure that developed countries built at considerable costs. The national incomes of the African countries is also a major constrain towards acquiring the conventional power systems. Under these circumstances, the only option for most African countries is the development and harnessing of the available renewable energy resources. These may provide only small to modest capacity systems. However, the flexibility of small size of renewable systems such as solar thermal, photovoltaic and wind energy can be ideal for Africa's needs. Another advantage associated with small size is speed of construction. Wind farms, for instance, can take less than a year to build. Also, the smaller capacity of renewable plants allows them more easily to match incremental changes in load growth and to meet the requirements of small load centers.

The major alternative energy resources abundant throughout the African continent are solar energy (thermal and photovoltaic), wind energy, wood and biomass, and biogas production. In making renewable energy consumption sustainable and acceptable to other socioeconomic parameters of development, the following must be considered [2]:

- Sustainability of the environment through appropriate resource management;
- Economic sustainability through infrastructure and service development that keeps affordability firmly to the front because of the disadvantaged rural populations;
- Social sustainability through ensuring that the poor benefit, and that women's incomes and concerns, legal rights for all, and children's rights are all appreciated and supported;
- Administrative sustainability through ensuring that there is administrative capacity for programme implementation, and that this will be maintained or increased over time.

For the purpose of this paper, four African countries, namely South Africa, Egypt, Nigeria and Mali, were considered as representative of the various spectra of development in the continent and a review is presented on the renewable energy policies of these countries and how far these policies are meeting up to the challenges of sustainable development.

2. Energy use pattern

2.1. South Africa

The Energy Policy Document of South Africa [3] seeks to attain 15% renewable energy contribution to the national energy mix within this decade. This is possibly the most ambitious renewable energy aspiration anywhere in the continent. The South African economy is energy intensive and dominated by non-renewable energy resources. Coal provides 75% of total fossil fuel consumption and 91% of electricity generation. More than two thirds of South Africa is electrified [3], the highest in the continent, as compared with one third in Nigeria [4] and 5% in Mali [5]. A number of public research institutes in South Africa and the private sector are leading the drive towards renewable energy development. So far an appreciable local capacity has been built for renewable energy development and utilization in the country and this provides a good model for other African countries especially those in the New Partnership for African Development (NEPAD) initiative.

A recent study conducted by the South African Department of Minerals and Energy (DME) and sponsored by the Danish Cooperation for Environment and Development (DANCED), extensive survey of the renewable energy market in South Africa was carried out. They also organized several capacity building activities under the name Capacity Building Project in Energy Efficiency and Renewable Energy (CaBEERE) [6]. The overall objective of the project was, 'an increased use of Renewable Energy and Energy Efficiency throughout South Africa to maximize the energy sectors' contribution towards sustainable development'[6]. The Project Components and outputs were Energy Efficiency, Renewable Energy, Capacity Building, Management, and Information and Participation. Since 2001, CaBEERE has implemented many projects in these key areas.

Under Renewable Energy, baseline studies have been carried out on micro-hydro power, solar and wind energy technologies. A 'Green Power' Brochure on Business Opportunities in South Africa for Renewable Energy Independent Power Producers was also launched to encourage investment in this sub-sector [7]. Technical Standards and Certification (TSC) for renewable technologies has also been completed in 2003. Other studies carried out include renewable energy strategy and market rules formulation. The reports so far compiled [7–14] provide important information and vital statistics on the solar and renewable energy industry in South Africa, giving assessment of their relative position and trends in the market place and possible opportunities that were currently not being exploited.

The solar energy radiation and wind energy data for South Africa is quite extensive. Several public institutions, such as the National Building Research Institute (NBRI) and the Energy Research Center (ERC), Cape Town are handling this [15,16]. On an average, about 24 GWhr/m^2 per annum of solar radiation is received in the country. With a large land mass of 1.2 million squire kilometers (a large proportion of it being desert) South Africa is a potentially solar rich country. It is interesting to note that while South Africa presently imports some solar energy technology (photovoltaic especially), there is a large local production capacity and some of their products (solar thermal mainly) are being exported.

2.2. Egypt

The North African state of Egypt is the second most industrilised economy in the African continent. Egypt is a significant oil and natural gas producer producing an average of about 620,000 barrels per day (bbl/d) of crude oil in 2003. Egypt had installed generating capacity of 17.7 GW (Gigawatts) as of 2001, with plans to add 4.5 GW of additional generating capacity by 2007. Around 84% of Egypt's electric generating capacity is thermal (fired by natural gas), with the remaining 16% hydroelectric, mostly from the Aswan High Dam [17]. In the area of renewable energy development, Egyptian government in 1986 established the New and Renewable Energy Authority (NREA) whose mandate was to develop and diffuse the application of solar (thermal and photovoltaic), wind and biomass energy technology in the Egyptian economy. NREA has targeted a 3% of total electricity generation from solar and wind by 2010 [18]. They also have several laboratories for testing and certification. In addition, NREA carries out training programs for both public and private sectors.

While solar water heaters, about 200,000 installed by the year 2000 [18], and solar desalination plants are quite in common use in Egypt, one other area of great achievement is in harnessing wind energy. Along the red sea coast, wind speeds exceed 10 m/s. Zafarana wind farm is one major development in wind turbines utilization in the coountry with a total 222 turbines providing an installed capacity of 140 MW and plans to expand this to 600 MW by year 2010 [19]. This is possibly the largest wind farm any where in Africa and a lot needs to be learnt from this project by other wind-endowed African countries. Egypt is also planning to build a Solar Power Plant at Kureimat as a Build-Operate-Transfer (BOT) project, which will have 30 MW of solar capacity initially out of a total planned capacity of 150 MW [20].

Over 80% of Egypt receives annual solar radiation in excess of 2000 kWh/m^2 per year, and over 90% of its land area is available for use to harness this resource. This makes the potential for solar thermal power generation in Egypt one of the best in Africa. In a country that is predominantly desert, the Nile River provides the life-blood for Egypt's population and sustainability is very crucial. With over 90% of the population living astride the Nile river [17], environmental issues are a central component of Egyptian life. Population growth, modernization, and increased economic development have brought environmental problems, especially air pollution, to the forefront. In Cairo, for example, emissions from vehicles using conventional fuels, together with sand blowing in from the adjacent Sahara desert and other discharges from small-scale smelters in the city combine to create high levels of particulate matter in the air, a deadly combination for a densely populated capital. This brings to the forefront, the importance of expanding the role of renewable resources in the Egyptian national energy mix.

2.3. Nigeria

Nigeria is Africa's most populous nation (over 100 Million) and the largest producer of crude oil (with 2.3 Million barrels per day, making it the sixth world exporter). More than two thirds of Nigerians live in the rural areas where the major energy resource is fuel wood, the conventional petroleum fuels being, ironically, scarce in these rural areas [21]. The fuel wood is used for cooking, water heating, and generation of warmth during the harmattan

winds (North-eastern winds that blow across the Sahara desert, four month every year) and in rural cottage industries (such as pottery, blacksmithing, brown sugar, etc.). Fuel wood consumption in Nigeria in the mid 1980s was put at 43 million metric tones per annum [22] giving a per capita consumption of about 500 kg per annum. The use of fuel wood on this large scale without replenishment has obvious environmental side effects, the most glaring being desertification, now eating deep into Nigeria's savannah heart land at a very alarming rate. Unless something is done, and done quickly, the rich agricultural farmlands of the Northern states of Nigeria would in no distant future become shifting sand dunes.

Cooking by far accounts for the largest use of fuel wood in Nigeria [21]. Alternative energy sources have to be provided to the rural populace to replace fuel wood. Some traditional users may find it difficult to make a change and for these, there is need to introduce improved wood stoves to ensure that there is drastic reduction in wood fuel consumption as a result of better combustion efficiency. Different research institutes and centers have developed several new improved stoves across the globe and some of these need to be popularized. Typical examples are available in the Internet [22].

Nigeria's alternative energy resource base is very vast. Taking solar energy alone, it was estimated in 1987 [23] that if only 0.1% of the total solar energy radiant on the country's land mass is converted at an efficiency of 1%, it would meet the total energy demands of the nation. On an average, Nigeria receives 20 MJ/m^2 per day with little variation throughout the year [4]. Two solar energy research centers were established in Sokoto and Nsukka in 1983, but unfortunately these were grossly under funded and as such the little work done in the past two decades, mainly in solar thermal appliances, have already been surpassed elsewhere in the globe and there is little interest in the private sector investing into further development of these devices.

Nigeria must take lessons from the very pragmatic energy policies in Egypt and South Africa. In spite of recent efforts to reinvigorate the renewable energy sector in Nigeria [24], the institutional framework is still very weak and the following must be addressed to give renewable energy the required impetus:

- Enhancing the role of renewable energy in the overall energy policy and the national energy mix.
- Introduction of comprehensive standards and codes of practice;
- Promulgation of appropriate legislation to support the institutional framework;
- The integration of renewable energy development with environmental factors and with energy efficiency (presently most industries in Nigeria are operating below 50% capacity due to an unreliable public electric utility service).
- A well articulated renewable energy Research and Development agenda over the coming years and its funding; and
- Training of quality personnel at both technical and engineering levels in order to attain self sufficiency.

2.4. Mali

The West African state of Mali represents a case study of most Sahelian states in the continent. The population of Mali is about 11 million with 28% of the population residing

in urban settings. In Bamako, the capital of Mali, only about 25% of the population have access to electricity, and in rural areas this figure is less than 1% [5]. On the overall, access to electricity in Mali is just about 5%. Mali is part of the Sahara desert with 65% of the country now desert or semi-desert. The rapid desertification of Mali is due to on-going droughts, over-grazing, topsoil erosion, harsh desert winds, and the scavenging of trees for firewood. The energy sector is mostly based on traditional fuels, with low per capita consumption. About 90% of the energy consumed comes from the unsustainable use of fuel-wood. Biomass producing land areas have been disappearing at an alarming rate of 9,000 ha per year [25], leading to soil erosion and desertification and making this the most serious environmental issue linked to energy consumption.

A number of programs, mostly photovoltaic (PV), have been deployed in the country to date, many from donor agencies [5,26]. Solar energy for evening lighting is particularly important in rural desert climates. In these climates, the workday is generally inactive, especially around the hottest part of the day. Adequate lighting at night would allow people to continue working in the evening, thus extending the workday and stimulating the economy [27,28]. Development of other technologies, especially solar thermal, such as solar dryers, solar cookers and solar absorption refrigerators, as well as other renewable resources such as micro-hydro, wind power, small scale gasifiers and biogas digesters are also very important in order to have a more balanced renewable energy development. The use of solar cookers developed in Bamako by researchers in the 1980's has not found much success because of the poor efficiency of the cookers, their outdoor nature and the fact that in the evening, towards dinner, there isn't enough sunshine for cooking [25]. The Malian government is, however, encouraging private enterprises to take the lead on renewable energy commercialization issues including distribution, installation, and maintenance of installed systems.

Certainly, wood is the most used fuel in Mali and the Sahel region generally, but it is often combined with other energy sources and in particular ways. In the first place, wood is used year round in the cities and in some parts of the provinces. Besides wood, which is getting scarce, millet stalks, cotton and sesame stalks, cow dung, etc., are used. Many women use millet stalks to light the fire or for all of their cooking. Thus, in a number of villages millet stalks wholly cover fuel requirements for many months, especially in the dry season due to inadequacy of the wood-fuel [25]. Mali has very little other natural resources and the importation of fossil fuels, in particular, constitutes a heavy burden on the country's budget. Since the 1973 oil price shock, the prices of crude oil based fuels had increased dramatically, sometimes requiring as much as 20 percent of national incomes of Sahelian states [26]. One major solution to Malian energy crisis is to adapt some of the strategies already being used in Egypt and South Africa. It is also necessary, as in the case of Nigeria, to reduce wood-fuel consumption through the use of improved stoves as argued earlier.

3. Discussions

The African continent presents an array of varied energy mix, resources and policies. What is common, however, is the availability of abundant renewable energy

resources in virtually every country. While South Africa and Egypt present very encouraging models of renewable energy harnessing and utilization, Mali provides a case study of urgency in addressing sustainable energy policy especially in view of the environmental degradation associated with the traditional energy use patterns. Nigeria is a case of abundance of both conventional and renewable resources but with very poor infrastructural support to harness the renewable resources. In fact, the plight of Nigerian rural poor is not significantly different from that of their Malian counterparts. Domestic use accounts for most of the energy consumption, and fuel wood is most frequently used. Rural women spend more than two hours a day, on average, finding wood. The main constraints to access of other forms of energy in the rural areas are the high capital costs for electrical grid connection, installation and maintenance of appliances and limited distribution of petroleum fuels due to the poor or lack of private or public transport, and limited support services.

Renewable energy resources, abundant in all the African countries, would provide a major breakthrough in finding a solution to this energy crisis. Energy is indeed a catalyst for economic growth, and lack of adequate energy services is certainly a constraint to development. It limits the potentials of meeting basic needs of those who need energy to undertake essential domestic, agricultural, and educational tasks; to support health and transport services, and to initiate or develop manufacturing or trading enterprises. The use of the renewable resources to meet these developmental targets should be done in such a way as to make it sustainable, taking all the environmental factors into consideration. In this respect, the following are suggested framework in the harnessing of renewable resources in Africa for sustainable development:

- A rural electrification drive based on Photovoltaic power systems should be pursued for supplying energy to homes, schools, clinics, small and medium scale farms, and small businesses. With the development of new and cheaper technologies for photovoltaic conversions, such as the use of polycrystalline silicon and nano-technology depositions, the capital cost for this should be coming down [29]. Operating costs are almost negligible.
- A deliberate policy to develop local capacity and distribution of solar thermal appliances for cooking, water heating, cooling, drying, etc.
- Development of improved wood cookers, local capacity for their production and popularization especially among the rural population. Along with this, there is need for improved production technologies for charcoal (widely used in the Sahel) that are efficient and appropriate.
- *Forestry*: the promotion of agro-forestry and wood lots products is another important initiative for sustainability of the use of fuel wood in the rural areas. This will also add to local employment. While commercial forestry has a bad name in many countries due to conflicts over land, water use, environmental impacts and labour practices, these can be properly resolved at a local level.
- The development of rural service centres to provide information and advice on energy use and technologies, selling of energy related goods (e.g. low power appliances), repair services and training in equipment maintenance. These service centres could be linked to agricultural or small business programs.

- Development of workable strategies to integrate energy and sustainable development concerns into decision making in Africa and this should cover
  - An energy planning process that incorporates local participation in needs assessment and prioritization.
  - The use of integrated energy planning (IEP) framework by local and national governments in Africa that focuses on the requirements of rural population and makes a range of appropriate energy resources available taking into consideration the environmental impacts.
  - Integrating energy planning with other rural development initiatives such as land reform, housing, health care and education.

A major area of concern raised by some writers on sustainable development [30,31] are the many barriers to development in the African continent such as abject poverty, poor state of health and education and environmental degradation. However, the solution to these barriers lies to a large extent in addressing the energy challenges facing the continent first and foremost as reliable and sustainable energy supply forms the very basis for solving the other socio-economic problems.

4. Conclusions

Africa is facing a serious energy crisis. This is ironically not due to lack of energy resources, but rather the poor state of infrastructural support and appropriate technology to harness these resources, especially the renewable ones. This is coming at a time when world attention is focused more on economic growth and trade liberalization under an aggressive globalisation drive. For Africa not to be left out, its energy needs must be addressed with an utmost sense of urgency. A matter of immediate concern in the energy quagmire in most African countries is the forest resource that is gradually declining, the supply of fuel wood becoming more difficult to sustain and demand already exceeding the potential supply. In many countries this has already created very serious environmental degradation and desertification. Whatever approach we adopt to address these problems, we must ensure that the solutions are sustainable and the alternatives to be provided must make economic sense to the rural user.

Of the four African countries studied in this paper, South Africa provides an encouraging model in solving Africa's energy crisis and the efforts in Egypt are quite encouraging. Mali, a typical poor Sahelian African country presents a case of how critical the energy crisis in Africa is and the need to fortify and accelerate the modest initiatives being undertaken there. Nigeria has a large energy resource base, both conventional and renewable resources, but these are not adequately harnessed. Appropriate framework has therefore been suggested in the paper for the development and sustainability of renewable energy resources in Nigeria and the continent at large. One major out come of this review is the need for African countries to pool resources together in information sharing, and the development of a resource base for training and the sharing of skills.

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